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THESIS

OPTIMALLY LOCATING
CONTAINER STUFFING SITES

by

Robert S. Guarino

September, 1993

Thesis Advisor: Robert F. Dell

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Military Traffic Management Command Eastern Area (MTMCF A) is the headquarters command responsible for land cargo movements in the eastern United States and Europe. MTMCEA stuffs all cargo destined for Europe into containers. This thesis develops and solves a mixed linear integer program to determine the optimal number and location of container stuffing sites. The formulation models MTMCEA operations with minimization of both cost and time delay. The model was adjusted for analyses of many scenarios including which sites to open ignoring time, varying costs, and limiting sites available. All versions of the model solve in under 2 minutes and indicate a potential for saving up to half a million dollars for MTMCEA container stuffing operations.

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OPTIMALLY LOCATING CONTAINER STUFFING SITES

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Submitted in partial fulfillment
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ABSTRACT

Military Traffic Management Command Eastern Area (MTMCEA) is the headquarters command responsible for land cargo movements in the eastern United States and Europe. MTMCEA stuffs all cargo destined for Europe into containers. This thesis develops and solves a mixed linear integer program to determine the optimal number and location of container stuffing sites. The formulation models MTMCEA operations with minimization of both cost and time delay. The model was adjusted for analyses of many scenarios including which sites to open ignoring time, varying costs, and limiting sites available. All versions of the model solve in under 2 minutes and indicate a potential for saving up to half a million dollars for MTMCEA container stuffing operations.

DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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EXECUTIVE SUMMARY

This thesis develops and solves a mixed linear integer program to determine the optimal number and location of Military Traffic Management Command Eastern Area (MTMCEA) container stuffing sites. Model results indicate that approximately half a million dollars may be saved annually by adding a container stuffing site at Mechanicsburg, PA.

MTMCEA is the headquarters command responsible for land cargo movements in the eastern United States and Europe. All cargo destined for Europe must be "stuffed" into containers before being shipped overseas. The derived model is for peacetime shipments of "normal" cargo (not priority, sensitive, hazardous, or urgent). Only international shipments of less than container loads apply.

Container stuffing operations are only a small part of MTMCEA's overall operations. Less than container loads of cargo shipped within the Continental United States (CONUS) are not sent to container stuffing sites. CONUS and international shipments of full container loads are stuffed at (or near) the origin, and sent directly to the destination. Only international shipments of less than container loads of cargo must be "stuffed" into a container before being shipped overseas. This amounts to approximately 320,000 Measurement Tons (MTONs), and 210,000,000 pounds, of cargo per year.

MTMCEA seeks primarily to minimize the cost of container stuffing operations. A secondary objective is included to account for time. The model assumes significant time differences occur only at non-port container stuffing sites, while waiting for enough cargo to use a rail car as transportation. The delay waiting for sufficient cargo to arrive is minimized. This assumption was necessitated by the lack of time data.

Using only current container stuffing locations MTMCEA's annual operating cost is estimated at 13 million dollars. The model recommends the addition of Mechanicsburg as a new stuffing location which results in half a million dollar reduction in annual cost. As this is only a small savings, an extensive sensitivity analysis was conducted.

The savings are based on an optimistic (negotiated) MTMCEA rail rate. When this rate is replaced by a more conservative (published) rail rate, the model's least cost solution indicates that only the 3 current container stuffing locations should remain in operation. Furthermore, fixed costs would have to raise to about 500%, transportation costs would have to reduce to about 10%, or cargo would have to be reduced to about one-fifth of current values before any of these sites would be recommended for closure. These published rail rates have to be decreased to 40% before other container stuffing locations open.

When MTMCEA is limited to only the current container stuffing sites, fixed costs would have to raise to about 500%, transportation costs would have to reduce to about one-fourth, or

cargo would have to be reduced to about one-fifth of current values before a site would be recommended for closure.

These results indicate the current configuration of locations are very near the least cost solution for any potential changes to demand or costs. However, saving opportunities are found to exist when a new location (Mechanicsburg, PA) was added. Mechanicsburg warrants additional consideration and analysis as a potential new container stuffing site.

I. INTRODUCTION

A. MILITARY TRAFFIC MANAGEMENT COMMAND EASTERN AREA

Military Traffic Management Command (MTMC) is the headquarters command responsible for land cargo movements in the United States (US) and overseas. All defense cargo being shipped by land, rail or sea is dependent on MTMC service contracts. In peacetime MTMC maintains a small presence at many ports while handling shipping functions for Department of Defense (DOD) cargo. In wartime MTMC expands its operation to a variety of ports as required to transport the Army to war.

MTMC is the senior commander of MTMC Eastern Area (MTMCEA) and MTMC Western Area (MTMCWA). MTMCEA handles all military shipments on the East Coast of the US and in Europe. MTMC headquarters (MTMCHQ) often negotiates carrier shipping rates and sets guidelines for the conduct of MTMCEA's operations. In the absence of MTMC guidance, MTMCEA may negotiate its own shipment rates and establish its own operational guidelines.

Both MTMC and MTMCEA had questions about the conduct of MTMCEA's container stuffing operations. Neither agency was sure that the operation was being conducted in the most efficient manner possible. This thesis develops and solves a mixed linear integer program to determine the optimal number and location of MTMCEA container stuffing sites.

B. CONTAINER STUFFING OPERATIONS

A container, or MILVAN, is a 20 foot x 8 foot x 8 foot rectangular metal box. Forklifts place cargo inside the containers at locations referred to as container stuffing sites. Without the benefit of any detailed analysis concerning the optimal location of container stuffing sites, MTMCEA uses 3 ports on the east coast (Bayonne, New Orleans, and Norfolk). After being "stuffed" at the ports, the containers can be moved anywhere in the US government transportation network (worldwide), by trucks, rail, ships and/or planes.

Container stuffing operations are only a small part of MTMCEA's overall operations. Less than container loads of cargo shipped within the Continental United States (CONUS) are not sent to container stuffing sites. CONUS and international shipments of full container loads are stuffed at (or near) the origin, and sent directly to the destination. Only international shipments of less than container loads of cargo must be "stuffed" into a container before being shipped overseas. This amounts to approximately 320,000 Measurement Tons (MTONs), and 210,000,000 pounds, of cargo per year.

C. OVERVIEW OF THESIS

MTMCEA requested an analysis of its container stuffing operations, with the restriction that cargo must pass through one of the currently used container stuffing sites (ports of

Bayonne, Norfolk, New Orleans). Both MTMCEA and MTMC are also interested in the broader issue of determining the optimal number of container stuffing sites and locations. The objective guiding these decisions is a composite of both the cost and the time required to ship cargo. MTMCEA would like to perform its operations in as frugal a manner as possible. However, it cannot afford to sacrifice too much time to achieve monetary savings.

This thesis determines the optimal number and location for container stuffing activities within Military Traffic Management Command Eastern Area (MTMCEA). Chapter II surveys related literature for similar facility location problems. Chapter III presents a mixed linear integer program with detailed discussion of the available data and their implications for this model. Using the model of Chapter III, computational performance for a variety of operational scenarios is listed in Chapter IV. Chapter V provides conclusions and recommendations. Appendix A lists additional modelling assumptions. Appendix B describes the derivation of data.

II. RELATED STUDIES

The operations research literature related to facility location problems is extensive. Sielken [Ref. 1] and Alcouffe [Ref. 2] introduce the concept of locating plants to minimize both the costs of production and transportation. Unlimited facility capacity, and linear costs for shipment routes are used. However, the destinations (as opposed to the origins) have a fixed demand for cargo.

Sielken determines that exhaustive enumeration is impractical for large sets of sources and destinations. An iterative approach between evaluating optimal demand allocations and optimal source location configurations is used. The approach yields only local optimal solutions. Computational performance is reported for a model consisting of 4 sources with 8 potential locations each, and a single commodity demanded by 16 destinations.

Alcouffe's work uses the same basic scenario as Sielken. However, Alcouffe also offers an alternative to Sielken's method of finding the optimal source locations to be tested. A heuristic procedure is used which drops plants out of the possible local optimal solution. This effectively reduces the amount of computing time required to obtain a solution. An example problem has 20 plants and 40 destinations.

Erlenkotter [Ref. 3] investigates a procedure to obtain the optimal solution for an uncapacitated facility location problem. Fixed charges to open facilities are introduced. He uses a solution approach based on the dual of the formulation to find an integer based primal solution. He finds the optimal solution is obtained faster than other methods. The largest example has 24 warehouses and 50 demand locations.

Klincewicz [Ref. 4] accounts for time as a factor. He introduces economies of scale along the routes, as a function of volume. The delays waiting for adequate volume are minimized by the use of holding costs. He also introduces the concept of consolidating shipments versus sending them directly to the destinations. He offers several heuristic procedures based on linear costs to terminals and destinations. An example problem of 50 sources, 4 terminals and 50 destinations is solved in under 2 hours on an IBM 3090-200CP computer.

Van Roy [Ref. 5] investigates a capacitated facility location problem. He uses Lagrangian relaxation and Benders decomposition in tandem, taking advantage of both the primal and dual structure of the problem. Benders decomposition exploits the primal structure by fixing primal variables. Then Lagrangian relaxation fixes certain primal constraints with values obtained from the dual. Problems of up to 100 possible facilities and 200 customers are solved up to 10 times faster than other approaches for these problems.

Francis [Ref. 6] analyzes several different methods of viewing and solving mixed-integer problems. He advocates enumeration as the only guaranteed optimal solution, but offers no computational results. He also investigates "planar" location models, warehousing location models, and network location models. His article is primarily useful as an overall synopsis of methods to consider prior to formulating similar problems.

Louveaux [Ref. 7] investigates the Hakimi theorem which states that under certain assumptions the optimal location of a firm is at a node in the shipping network. He expands on the idea by allowing varying shipping rates, shipping mode changes and fixed costs. He also shows that when shipping mode changes exist the junction points can also be optimal locations. No applicable computational experience is listed.

Finally, List [Ref. 8] introduces the idea of stochastic risks associated with the routes and locations. For the most part, linear programming models have not included stochastic coefficients or variables. List offers ways that they may be incorporated into future models. He offers no computational experience.

III. MODEL

A. OBJECTIVE

This thesis develops and solves a mixed linear integer program to determine the optimal number and location for container stuffing activities within MTMCEA. It developed around the needs of MTMCEA and the data that were available in MTMCEA records. Many assumptions had to be made before a representative model was developed. Some of the more important assumptions are listed below.

The model is for peacetime shipments of "normal" cargo (not priority, sensitive, hazardous, or urgent). Of this normal cargo, only international shipments of less than container loads apply. The level of this type cargo is such that the available shipping routes can be considered uncapacitated.

Because container stuffing operations are usually only a small portion of a terminal's operations, all stuffing sites and ports are assumed to have infinite capacity. Since no data exist for the unstuffing operations overseas, the costs from all ports to overseas destinations are assumed equal. This results in the ports being modelled as the destinations for the cargo.

MTMCEA seeks primarily to minimize the cost of container stuffing operations. A secondary objective is included to account for time.

A list of additional assumptions is included in Appendix A.

B. FORMULATION

The formulation models MTMCEA's operations with minimization of costs and time as the objectives. Listed below is the notation for the model and the formulation in Naval Postgraduate School (NPS) format.

1. Indices

- i = source of cargo needing stuffing operations,
- j = all possible container stuffing sites.

2. Data

- NONPORTS = set of possible container stuffing sites that are not ports,
- $TRANSCOST_{ij}$ = transportation costs per MTON from supply location i to container stuffing site j,
- $FIXED_j$ = fixed cost to operate container stuffing site j,
- $STARTUP_j$ = cost of opening container stuffing site j (cost assumed zero if site already exists),
- $CLOSEUP_j$ = cost of closing container stuffing site j (cost assumed zero if site does not yet exist),
- $HANDLING_j$ = handling cost per MTON at container stuffing site j,
- $RAIL_j$ = rail cost to nearest port per MTON from container stuffing site j,
- $CARGO_i$ = MTONs originating at supply location i,

- **$TOMAX_{ij}$** = maximum amount of MTONs that could be sent from supply location i to container stuffing site j,
- **$TOMIN_j$** = minimum required MTONs shipped to container stuffing site j,
- λ = weight of the cost objective ($0 \le \lambda \le 1$). The objective measuring the time delay is weighted $(1-\lambda)$.

3. Variables

- X_{ij} = MTONs cargo shipped from supply location i to container stuffing site j,
- Y_j = 1 if container stuffing site j is open, 0 otherwise.

4. Formulation

$$MINIMIZE\ \lambda \times ((\sum_i \sum_j (X_{ij} \times (TRANSCOST_{ij} + HANDLING_j + RAIL_j))$$

$$+ (\sum_j (Y_j \times (FIXED_j + STARTUP_j)))$$

$$+ (\sum_j ((1 - Y_j) \times CLOSEUP_j)))$$

$$+ ((1 - \lambda) \times ((-1) \times (\sum_i \sum_{j \in NONPORTS} X_{ij})))$$

$$\sum_i (X_{ij}) \ge TOMIN_j \times Y_j \quad \forall (j) \qquad (1)$$

$$X_{ij} \le TOMAX_{ij} \times Y_j \quad \forall (i,j) \qquad (2)$$

$$\sum_j (X_{ij}) = CARGO_i \quad \forall (i) \qquad (3)$$

1) A minimum amount of MTONs must be received in order to open a container stuffing site.

2) Cargo can only be shipped to open container stuffing sites.

3) Each supply location must ship all of its cargo to a container stuffing site.

C. TIME OBJECTIVE

A useful model needs to account for the time required to ship cargo to its destination. However, time data is not collected for shipments of less than container loads of cargo within MTMCEA. This model assumes the only significant time differences occur at the container stuffing sites at non-port locations, while waiting for adequate amounts of cargo to warrant the use of a rail car.

Uniform flow of cargo over the duration of the cargo shipment periods is assumed. If the railcars must be loaded to capacity (i.e., 4 MILVANs per flatcar) prior to shipment, there is a time delay while waiting for enough cargo to arrive at the container stuffing site to fill 4 MILVANs.

For example, a location which stuffs 100,000 MTONs of cargo annually would stuff approximately 274 MTONs of cargo per day. Since 32 MTONs fit in a MILVAN, a site requiring 4 MILVANs per flatcar will send a railcar about twice a day (274 MTONs ÷ 32 MTONs/MILVAN = 8.56 MILVANS/day;

8.56 MILVANS/day ÷ 4 MILVANs/flatcar = 2.1 flatcars/day). If the same site requires only 1 MILVAN per flatcar, it will send about 8 railcars per day.

The model minimizes time delay at non-port open container stuffing sites by maximizing the volume shipped to these sites. To maximize the volume shipped, the model minimizes the negative of the volume shipped. Constraint (1) is included to guarantee a minimum volume at each location (maximum time delay). A bi-objective model, with weighted objectives of costs and volumes (and hence time), is developed above. It allows the planner to subjectively weigh the importance of each of the objectives by varying the weighting coefficient (λ).

The bi-objective model only guarantees better service (less time) if the container stuffing sites which are not ports are faster than the ports' container stuffing operations. However, the ports' container stuffing times are not known. Hence, caution must be used when forming conclusions from the model with regard to time.

IV. COMPUTATIONAL EXPERIENCE

Four model variations are investigated in this chapter: the bi-objective model, 2 models excluding time considerations (with published and negotiated rail rates), and a model excluding any new container stuffing sites.

A detailed analysis of MTMCEA data related to container stuffing operations is conducted to develop the necessary model inputs and is contained in Appendix B. Tables resulting from the process are shown below.

Table I provides a list of possible container stuffing sites as well as the code used for subsequent tables.

Table I CODES USED IN TABLES

NAMES	CODE USED IN TABLES
ANNISTON, AL	ANNAL
JACKSONVILLE, FLA	JAXFL
ATLANTA, GA	ATLGA
NEW ORLEANS, LA	NORLA
GULFPORT, MISS	GLPMI
CHERRY PT, NO CAL	CHPNC
BAYONNE, NJ	BAYNJ
COLUMBUS, OH	COLOH
MECHANICSBURG, PA	MECPA
PHILADELPHIA, PA	PHLPA
CHARLESTON, SO CAL	CHLSC
MEMPHIS, TN	MEMTN
NORFOLK, VA	NOFVA

The amount of cargo shipped annually is approximately 320,000 MTONs, shipped from 24 aggregated locations, with quantities varying from 383 to 123,884 MTONs per year as shown in Table II.

Table II SUPPLY LOCATIONS AND QUANTITIES

SUPPLIER	CODE	MTONs/YEAR
ANNISTON,AL	ANNAL	577.2
LONG BEACH,CA	LBHCA	8180.0
COL. SPRINGS,CO	CSPCO	1160.4
HARTFORD,CT	HRTCT	687.2
WASHINGTON,DC	WASDC	6268.8
JACKSONVILLE,FL	JAXFL	2531.2
ATLANTA,GA	ATLGA	10139.6
CHICAGO,IL	CHIIL	488.0
LEXINGTON,KY	LEXKY	195.2
NEW ORLEANS,LA	NORLA	14094.8
ST. LOUIS,MO	STLMO	533.2
GULFPORT,MI	GLPMI	582.0
CHERRY POINT,NC	CHPNC	842.0
BAYONNE,NJ	BAYNJ	80991.6
SENECA,NY	SENNY	383.2
COLUMBUS,OH	COLOH	18183.6
MECHANICSBURG,PA	MECPA	23930.0
PHILADELPHIA,PA	PHLPA	9183.6
CHARLESTON,SC	CHLSC	1342.8
MEMPHIS,TN	MEMTN	4368.8
DALLAS,TX	DALTX	9988.0
OGDEN,UT	OGDUT	1180.0
NORFOLK,VA	NOFVA	123884.8
SEATTLE,WA	SETWA	1890.8

The representative unit of cargo used throughout the thesis is one MTON, weighing 653.5 pounds. Trucks are used to ship all cargo to container stuffing sites. After cargo has been stuffed into a MILVAN it may be transported to ports by

rail or truck. The rates for one MTON shipped via rail and truck from the 24 sources to the 13 potential container stuffing sites vary from zero to 130 dollars per MTON (Tables III-VII).

Table III TRUCK TRANSPORTATION COST PER MTON ($)

	ANNAL	JAXFL	ATLGA	NORLA	GLPMI
ANNAL	0.0	49.14	28.54	49.14	45.24
LBHCA	109.20	115.96	111.54	104.26	105.50
CSPCO	88.66	99.19	91.00	88.14	88.66
HRTCT	77.28	77.28	74.16	92.36	89.57
WASDC	63.05	63.05	60.97	78.78	31.78
JAXFL	49.14	0.0	44.40	55.45	52.39
ATLGA	28.53	44.40	0.0	52.39	50.77
CHIIL	66.34	75.79	63.05	73.39	71.76
LEXKY	49.14	62.34	46.08	65.07	63.05
NORLA	49.14	55.45	52.39	0.0	26.72
STLMO	54.66	70.66	55.45	62.34	61.69
GLPMI	45.24	52.39	50.76	26.72	0.0
CHPNC	59.48	54.67	53.17	75.01	72.61
BAYNJ	73.39	73.39	70.07	88.66	88.14
SENNY	74.95	77.29	72.61	89.57	88.73
COLOH	56.16	69.29	55.45	73.39	71.76
MECPA	64.42	65.78	61.69	78.85	77.29
PHLPA	70.66	70.66	65.13	86.65	85.15
CHLSC	49.14	40.69	42.58	64.42	61.69
MEMTN	42.64	62.34	46.09	49.14	46.09
DALTX	63.05	75.79	69.29	53.17	55.45
OGDUT	102.96	111.54	102.96	101.73	101.72
NOFVA	61.69	59.48	55.45	77.29	74.17
SETWA	120.45	129.16	122.66	120.45	120.45

Table IV TRUCK TRANSPORTATION COST PER MTON (cont.)

	CHPNC	BAYNJ	COLOH	MECPA	PHLPA
ANNAL	59.48	73.39	56.16	64.42	70.66
LBHCA	122.66	124.80	113.62	120.45	122.66
CSPCO	101.72	101.72	88.14	96.53	99.13
HRTCT	61.69	33.15	61.69	45.24	39.39
WASDC	44.40	39.39	49.14	28.54	33.15
JAXFL	54.67	73.39	69.29	65.78	70.66
ATLGA	53.17	70.07	55.45	61.69	65.13
CHIIL	73.39	69.29	44.40	60.97	65.07
LEXKY	59.48	63.05	37.83	53.17	60.91
NORLA	75.01	88.66	73.39	78.85	86.65
STLMO	74.17	74.17	50.83	65.07	71.76
GLPMI	72.60	88.14	71.76	77.29	85.15
CHPNC	0.0	54.73	60.97	50.77	51.61
BAYNJ	54.73	0.0	55.45	39.39	28.54
SENNY	61.69	41.67	51.61	40.69	41.67
COLOH	60.97	55.45	0.0	45.24	52.39
MECPA	50.77	39.39	45.24	0.0	33.15
PHLPA	51.61	28.54	52.39	33.15	0.0
CHLSC	41.67	64.42	60.97	59.48	60.97
MEMTN	71.76	78.85	59.48	71.76	75.79
DALTX	88.66	95.16	34.65	91.0	92.37
OGDUT	113.62	111.54	99.13	106.73	111.54
NOFVA	34.97	45.24	55.45	42.65	41.67
SETWA	129.16	124.80	115.96	122.66	124.80

Table V TRUCK TRANSPORTATION COST PER MTON (cont.)

	CHLSC	MEMTN	NOFVA
ANNAL	49.14	42.64	61.69
LBHCA	118.24	101.73	122.72
CSPCO	99.13	75.79	100.42
HRTCT	70.66	86.65	52.39
WASDC	53.17	71.76	37.83
JAXFL	40.69	62.34	59.48
ATLGA	42.58	46.09	55.45
CHIIL	71.76	55.45	70.66
LEXKY	54.73	50.83	56.16
NORLA	64.42	49.14	77.29
STLMO	70.07	42.58	72.61
GLPMI	61.69	46.09	74.17
CHPNC	41.67	71.76	34.97
BAYNJ	64.42	78.85	45.24
SENNY	70.07	77.29	54.67
COLOH	60.97	59.48	55.45
MECPA	59.48	71.76	42.64
PHLPA	60.97	75.79	41.67
CHLSC	0.0	62.34	49.14
MEMTN	62.34	0.0	71.76
DALTX	78.85	52.39	89.57
OGDUT	111.54	95.16	111.54
NOFVA	49.14	71.76	0.0
SETWA	127.01	113.62	127.01

Published rail rates from supply locations to the least expensive ports are listed in Table VI.

Table VI PUBLISHED RAIL RATES TO PORTS: 1 MTON w/4 MILVANs on 89-FOOT FLATCAR

	PORTS		
SUPPLY SITES	BAYONNE	NORFOLK	NEW ORLEANS
ANNISTON	-	-	11.2
HARTFORD	6.7	-	-
WASHINGTON	-	7.9	-
JACKSONVILLE	-	13.4	13.4
ATLANTA	-	-	12.0
CHICAGO	16.9	-	-
LEXINGTON	-	13.2	-
NEW ORLEANS	-	-	0.0
ST LOUIS	-	-	14.6
GULFPORT	-	-	5.2
CHERRY PT	-	7.6	-
BAYONNE	0.0	-	-
SENECA	9.6	-	-
COLUMBUS	13.8	13.8	-
MECHANICSBURG	7.6	-	-
PHILADELPHIA	5.9	-	-
CHARLESTON	-	12.1	-
MEMPHIS	-	-	10.7
DALLAS	-	-	12.1
NORFOLK	-	0.0	-

Negotiated rail rates to the least expensive ports are included in Table VII.

Other costs are included in Table VIII. Fixed costs for the 13 potential container stuffing sites range from $253,548 to $715,584 per year. The handling costs vary from $11.75 to $26.40 per MTON for the 13 potential container stuffing sites. Startup and closeup costs are considered zero due to being

Table VII NEGOTIATED RAIL RATES TO PORTS: 1 MTON w/4 MILVANS on 89-FOOT FLATCAR

	PORTS		
SUPPLY SITES	BAYONNE	NORFOLK	NEW ORLEANS
ANNISTON	-	-	6.68
HARTFORD	2.18	-	-
WASHINGTON	-	3.28	-
JACKSONVILLE	-	-	9.35
ATLANTA	-	-	8.07
CHICAGO	13.5	-	-
LEXINGTON	-	9.64	-
NEW ORLEANS	-	-	0.0
ST LOUIS	-	-	11.55
GULFPORT	-	-	1.23
CHERRY PT	-	2.97	-
BAYONNE	0.0	-	-
SENECA	4.31	-	-
COLUMBUS	9.07	-	-
MECHANICSBURG	3.06	-	-
PHILADELPHIA	1.51	-	-
CHARLESTON	-	6.61	-
MEMPHIS	-	-	6.67
DALLAS	-	-	8.49
NORFOLK	-	0.0	-

unavailable, but are included in the model for future analysis.

If non-port container stuffing sites are used the 3 ports must remain open, since the derived rail cost figures are to the least expensive port. There are no limits on the number of container stuffing sites allowed to open, or on the amount of cargo allowed to be stuffed at a site. However, there is a lower limit (20,000 MTONs which is about the cargo totals of

Table VIII OTHER COSTS ($)

	FIXED	STARTUP	CLOSEUP	HANDLNG
ANNAL	523,591	0	0	12.58
JAXFL	503,641	0	0	12.10
ATLGA	571,228	0	0	13.73
NORLA	493,495	0	0	14.50
GLPMI	588,156	0	0	14.13
CHPNC	532,840	0	0	12.81
BAYNJ	715,584	0	0	14.57
COLOH	671,038	0	0	16.13
MECPA	590,695	0	0	14.19
PHLPA	640,871	0	0	15.40
CHLSC	488,830	0	0	11.75
MEMTN	528,720	0	0	12.71
NOFVA	253,548	0	0	26.40

the third and fourth largest shippers) on the amount of cargo required for a container stuffing site to open.

The model was formulated and solved with the General Algebraic Modelling System (GAMS) [Ref. 9], using the XA solver [Ref. 10]. Using GAMS with the XA solver installed on an AMDAHL 5992-700A dual processor mainframe computer, all models solve in under 2 minutes. Each model generates 326 variables, 10 binary variables and 51 constraints.

A. RESULTS FROM BI-OBJECTIVE MODEL

With the current transportation network available to MTMCEA (i.e., only the 3 ports as container stuffing sites),

the least expensive way to truck and stuff all cargo is $13,073,566.

The bi-objective model considered in this section uses the negotiated rail rates, and allows cargo to be shipped two ways. One option is for cargo to be sent to one of several inland container stuffing sites and stuffed into a MILVAN. The MILVAN is then shipped to a port via rail. Cargo may also be sent from the supply locations directly to the ports to be stuffed in containers.

Tables IX through XII list the results for the bi-objective model when the number of MILVANs per flatcar are varied.

Table IX BI-OBJECTIVE MODEL: 4 MILVANs PER FLATCAR

λ	COST OBJECTIVE VALUE ($)	TIME/CARGO OBJECTIVE VALUE (MTONs)	CONTAINER SITES OPEN (W/3 PORTS)
.9999	12,502,300	59,586	MECPA, COLOH
.95	12,504,534	61,312	"
.90	12,623,337	82,169	" + ATLGA
.80	12,758,046	96,730	"
.70	12,758,046	96,730	"
.60	17,979,673	261,607	"+CHPNC, PHLPA

All values of λ<.6 have same cost, MTON and site entries as .6 has.

For the bi-objective model, when time is not considered (λ=.9999) and the least expensive rail option is selected (4 MILVANs per flatcar), the total cost is $12,502,300, using the 3 ports, and adding Mechanicsburg and Columbus as container

stuffing sites. Mechanicsburg and Columbus ship a total of 59,580 MTONs, at a rate of 1.275 railcars per day (every 18.8 hours). Compared to the baseline figure ($13,073,566), the bi-objective model's value is a reasonable savings.

For the bi-objective model with an increased emphasis on time (λ=.95), and 4 MILVANs per flatcar required, the total cost increases $2,234. Mechanicsburg and Columbus shipments increase a total of 1,726 MTONs. Cargo is now being shipped at a rate of about 1.312 railcars per day (every 18.3 hours). A decrease in time delay is bought for $2,234. This is still a significant savings over the baseline figure.

With an increased emphasis on time (λ=.7), and 4 MILVANs per flatcar required, the total cost is $12,758,046, using the 3 ports, and adding Mechanicsburg, Columbus, and Atlanta as container stuffing sites. Comparisons on time delay cannot be directly made since now there are 3 non-port container stuffing sites.

In Tables IX through XII, it is apparent that costs can be lowered below the baseline figure ($13,073,566) for all options of MILVANs per flatcar (1, 2, 3, or 4), by adding Mechanicsburg, and sometimes Columbus, as container stuffing sites. It should be noted that this model only guarantees better service (less time) if the container stuffing sites which are not ports are faster than the ports' container stuffing times, which are unknown. It should also be noted that using the bi-objective model with increased emphasis on

time that larger volumes of cargo can be shipped to non-port locations with little effect on cost.

Table X BI-OBJECTIVE MODEL: 3 MILVANs PER FLATCAR

λ	COST OBJECTIVE VALUE ($)	TIME/CARGO OBJECTIVE VALUE (MTONs)	CONTAINER SITES OPEN (W/3 PORTS)
.9999	12,620,757	59,053	MECPA, COLOH
.95	12,625,947	61,312	"
.90	12,637,254	63,203	"
.80	12,893,685	93,186	"+ATLGA
.70	12,953,155	96,730	"
.60	18,274,960	261,607	"+CHPNC, PHLPA -ATLGA

All values of λ<.6 have same cost, MTON and site entries as .6 has.

Table XI BI-OBJECTIVE MODEL: 2 MILVANs PER FLATCAR

λ	COST OBJECTIVE VALUE ($)	TIME/CARGO OBJECTIVE VALUE (MTONs)	CONTAINER SITES OPEN (W/3 PORTS)
.9999	12,743,641	49,065	MECPA
.95	"	"	"
.90	12,751,172	50,791	"
.80	13,266,267	93,186	"+ATLGA, COLOH
.70	13,339,690	96,730	"
.60	18,845,654	261,607	"+CHPNC, PHLPA -ATLGA

All values of λ<.6 have same cost, MTON and site entries as .6 has.

Table XII BI-OBJECTIVE MODEL: 1 MILVAN PER FLATCAR

λ	COST OBJECTIVE VALUE ($)	TIME/CARGO OBJECTIVE VALUE (MTONs)	CONTAINER SITES OPEN (W/3 PORTS)
.9999	13,005,474	23,930	MECPA
.95	13,042,195	48,577	"
.90	13,043,923	49,065	"
.80	13,096,569	53,215	"
.70	13,922,996	96,730	"+GLPMI
.60	20,174,020	261,607	"+PHLPA

All values of λ<.6 have same cost, MTON and site entries as .6 has.

B. RESULTS FROM MODEL EXCLUDING TIME CONSIDERATIONS

This model places no emphasis on the time objective (λ=1) and investigates the use of MTMCEA's published rail rates for cargo stuffed at non-port container stuffing sites and sent to ports. As shown in Tables VI and VII, the published rail rates are higher than the negotiated rail rates obtained from MTMCHQ historical data and used in the previous bi-objective model. The results supplied here can therefore be considered more conservative than previous results.

1. Results Using Published Rail Rates

The least cost solution for this model is to keep only the 3 ports operating as container stuffing sites (Table XIII). This results in a total cost of $13,073,566 for all

cargo shipments, compared to the previous least cost solution of $12,502,300.

Table XIII *PUBLISHED RAIL RATE MODEL: STUFFING SITE OPTIONS*

SITES FORCED CLOSED	RESULTING OPEN SITES	TOTAL COSTS
1 FREE	BAYNJ,NOFVA,NORLA	$13,073,566
2 NORLA	BAYNJ,NOFVA,GLPMI	14,556,080
3 NOFVA	BAYNJ,NORLA	16,970,225
4 BAYNJ	NOFVA,NORLA	17,882,966
5 NORLA,NOFVA	BAYNJ,GLPMI	18,485,779
6 BAYNJ,NORLA	NOFVA,GLPMI	19,435,287
7 BAYNJ,NOFVA	NORLA,MECPA,GLPMI	24,631,653
8 ALL PORTS	GLPMI,MECPA,PHLPA	26,270,518

By forcing the model to accept certain ports as open and others as closed, the increased cost for various options can be investigated. Table XIII indicates there are significant cost increases for any sites forced closed (i.e., closing New Orleans costs over $1,400,000).

a. Effect of Varying The Fixed Cost

The fixed costs at the ports may change due to a variety of economic reasons. Adjusting the fixed costs as multiples of their current values reveals the effects such increases have on container stuffing site closures and overall costs.

Table XIV indicates that fixed costs must be at least five times as large as current fixed costs before any container stuffing site should close (New Orleans). Also, not

until fixed costs are raised to nine times their original value are two sites closed (Bayonne and New Orleans). These results indicate fixed costs must rise substantially before greater transportation costs should be incurred.

Table XIV PUBLISHED RAIL RATE MODEL: FIXED COST OPTIONS

FIXED COST:	TOTAL COSTS:	CONTAINER STUFFING SITES		
		BAYONNE	NORFOLK	NEW ORLEANS
x 1	$13,073,566	OPEN	OPEN	OPEN
x 2*	14,536,193	OPEN	OPEN	OPEN
x 3	15,998,820	OPEN	OPEN	OPEN
x 4	17,461,447	OPEN	OPEN	OPEN
x 5	18,708,809	OPEN	OPEN	CLOSED
x 6	19,677,941	OPEN	OPEN	CLOSED
x 7	20,647,077	OPEN	OPEN	CLOSED
x 8	21,616,205	OPEN	OPEN	CLOSED
x 9	21,902,671	CLOSED	OPEN	CLOSED
x 10	22,156,219	CLOSED	OPEN	CLOSED
x 100	44,975,539	CLOSED	OPEN	CLOSED

* FOR EXAMPLE, ALL FIXED COSTS ARE DOUBLED AT EACH PORT.

b. *Effect of Varying The Truck Transportation Rates*

The only option available to ship unstuffed cargo is via truck. The transportation costs along the various truck routes were based on 40 percent of the quoted shipment rates for a generic unit of cargo. It is quite likely that these rates or this percentage could change higher or lower in the future. The effects such changes have on site closures and overall costs can be seen in Table XV.

Table XV indicates that the transportation costs have to be reduced to ten percent of the quoted shipment rates before a site closes (Norfolk). The reason that Norfolk closed first is because its variable handling costs were so much larger than the other two ports' costs. The table also indicates the addition of Mechanicsburg when truck rates are increased from 40% to 60%.

Table XV PUBLISHED RAIL RATE MODEL: TRUCK TRANSPORTATION RATE OPTIONS

TRUCK TRANSPORT COST (%):	TOTAL COSTS:	RESULTING OPEN SITES
100	$19,368,996	NORLA, BAYNJ, COLOH, MECPA, NOFVA
90	18,506,833	NORLA, BAYNJ, COLOH, MECPA, NOFVA
80	17,644,670	NORLA, BAYNJ, COLOH, MECPA, NOFVA
70	16,782,507	NORLA, BAYNJ, COLOH, MECPA, NOFVA
60	15,687,532	NORLA, BAYNJ, MECPA, NOFVA
50	14,432,964	NORLA, BAYNJ, NOFVA
40	13,073,566	" " "
30	11,713,578	" " "
20	10,347,409	" " "
10	8,660,754	NORLA, BAYNJ

c. *Effect of Varying The Rail Transportation Rates*

The transportation costs along the various rail routes were based on publications subject to change in the future. The effects such changes have on site closures and overall costs can be seen in Table XVI.

Reduced rail rates never cause the ports to close. Instead they allow other sites to open. Table XVI indicates

that the rail costs have to be reduced to 40 percent of the published shipment rates befcre a new site opens (Mechanicsburg).

Table XVI PUBLISHED RAIL RATE MODEL: RAIL TRANSPORTATION RATE OPTIONS

RAIL TRANSPORT COST (%):	TOTAL COSTS:	RESULTING OPEN SITES
100	$13,073,566	NORLA, BAYNJ, NOFVA
90	"	"
80	"	"
70	"	"
60	"	"
50	"	"
40	13,003,554	NORLA, BAYNJ, MECPA, NOFVA
30	12,890,627	"
20	12,649,601	NORLA, BAYNJ, MECPA, NOFVA, COLOH
10	12,396,760	"

d. Effect of Varying The Cargo Tonnage

It is quite likely that cargo quantities will shift higher or lower in the future. The effects such changes have on site closures and overall costs can be seen in Table XVII. It indicates that the cargo quantities have to be reduced to 20 percent of their original value before a site closes (New Orleans). Cargo must be increased to about 3 times the current level before a new site opens (Mechanicsburg).

Table XVII PUBLISHED RAIL RATE MODEL: CARGO TONNAGE OPTIONS

CARGO MTONS (%):	TOTAL COSTS:	CONTAINER STUFFING SITES OPEN
400	47,614,646	NORLA,BAYNJ,MECPA,NOFVA
300	36,213,469	"
200	24,684,506	NORLA,BAYNJ,NOFVA
100	13,073,566	"
90	11,912,472	"
80	10,751,378	"
70	9,590,284	"
60	8,429,190	"
50	7,268,096	"
40	6,107,003	"
30	4,945,909	"
20	3,741,761	BAYNJ,NOFVA
10	2,215,622	NOFVA

C. MODEL EXCLUDING NEW CONTAINER STUFFING SITES

The last iteration of the model was to limit the 3 ports as the only container stuffing sites possible. Since container stuffing only occurs at the ports, only truck transportation is used in this model.

The least expensive option for MTMCEA is to keep all 3 container stuffing sites at the 3 ports open. This will result in a total cost of $13,073,566. This cost figure is useful as a baseline value for which all other iterations of the model can be compared. It says if MTMCEA is going to move cargo via truck, operations should continue as they currently proceed, with the same 3 ports.

1. Effect of Forced Port Closures

Table XVIII indicates the least expensive port to close is New Orleans and it will cost MTMCEA about $1,800,000 to close.

Table XVIII NEW SITES EXCLUDED MODEL: PORT OPTIONS

	PORTS		
TOTAL COSTS:	**BAYONNE**	**NORFOLK**	**NEW ORLEANS**
$13,073,566	OPEN	OPEN	OPEN
$14,832,281	OPEN	OPEN	CLOSED
$16,970,225	OPEN	CLOSED	OPEN
$17,882,966	CLOSED	OPEN	OPEN
$18,763,834	OPEN	CLOSED	CLOSED
$19,874,287	CLOSED	OPEN	CLOSED
$21,516,906	CLOSED	CLOSED	OPEN

2. Effect of Varying Fixed Costs

The results of changing fixed costs are the same as listed for the published rail rate model.

3. Effect of Varying Truck Transportation Rates

The results of changing transportation rates are very similar to those of the published rail rate model. Differences only occur with respect to the sites open (Table XIX).

Table XIX NEW SITES EXCLUDED MODEL: TRUCK TRANSPORTATION RATE OPTIONS

TRANSPORT COST (%):	TOTAL COSTS:	PORTS BAYONNE	NORFOLK	NEW ORLEANS
100	$21,228,900	OPEN	OPEN	OPEN
90	$19,869,839	OPEN	OPEN	OPEN
80	$18,510,777	OPEN	OPEN	OPEN
70	$17,151,715	OPEN	OPEN	OPEN
60	$15,792,362	OPEN	OPEN	OPEN
50	$14,432,964	OPEN	OPEN	OPEN
40	$13,073,566	OPEN	OPEN	OPEN
30	$11,713,578	OPEN	OPEN	OPEN
20	$10,347,409	OPEN	OPEN	OPEN
10	$ 8,660,754	OPEN	CLOSED	OPEN

4. Effect of Varying Cargo Tonnage

The results of changing cargo tonnages are the same as listed for the published rail rate model.

V. CONCLUSIONS

This thesis develops and solves a mixed linear integer program to determine the optimal number and location of MTMCEA container stuffing sites. Model results indicate that approximately half a million dollars may be saved annually by adding a container stuffing site at Mechanicsburg, PA. Since MTMCEA container stuffing operations currently cost approximately 13 million dollars and these savings represent only a small reduction, an extensive sensitivity analysis was conducted.

The half a million dollar savings is based on an optimistic (negotiated) MTMCEA rail rate. When this rate is replaced by a more conservative (published) rail rate, the model's least cost solution indicates that only the 3 current container stuffing locations should remain in operation. Furthermore, fixed costs would have to raise to about 500%, transportation costs would have to reduce to about 10%, or cargo would have to be reduced to about one-fifth of current values before any of these sites would be recommended for closure. These published rail rates have to be decreased to 40% before other container stuffing locations open.

When MTMCEA is limited to only the current container stuffing sites, fixed costs would have to raise to about 500%, transportation costs would have to reduce to about one-fourth,

or cargo would have to be reduced to about one-fifth of current values before a site would be recommended for closure.

These results indicate the current configuration of locations are very near the least cost solution for any potential changes to demand or costs. However, saving opportunities are found to exist when a new location (Mechanicsburg, PA) was added. Mechanicsburg warrants additional consideration and analysis as a potential new container stuffing site.

APPENDIX A: ADDITIONAL ASSUMPTIONS

1. All the costs of transporting containers from ports on the US Atlantic coast to European locations are assumed to be equal. In other words, it costs the same amount to ship a container from New Orleans, to Bremerhaven, Germany, as it does from Bayonne, to Berlin, Germany. Due to restrictions on available data this assumption is necessary.

All cargo considered in this study must be "unstuffed" at a central location overseas, and then sent to its final destination. No cost database exists for this leg of the journey. This, coupled with the assumption that the cost of transporting stuffed containers from any Atlantic coast port to any European location are equal, allows the ports to be modelled as the destinations for the cargo.

2. Cargo levels at various supply locations (origins) is known and can be consolidated in this model for a variety of reasons. The primary reasons are geography and quantity. All shipments originating from locations outside MTMCEA are ignored (unless requested to be included in this study).

The model only considered supply sites which ship a minimum amount of cargo each year (10 MTONs). In effect, this limited the problem to manageable conditions, by eliminating the occasional shipment sites. Of course, the best way to meet all the demands of every shipper is to have a container

stuffing site at all supply locations. However, real world conditions require a minimum quantity criteria be included in the model.

3. The costs of opening or closing the military bases should not be included in this study. This is because a military base does not necessarily close due to the loss of container stuffing activities. Startup and closeup variables were included in the model to allow for future analysis of closing container stuffing sites.

4. Infinite capacity at each of the stuffing sites is assumed, since more labor can be hired, and space is not a limiting factor in this operation.

5. Assume no economies of scale (or price breaks) exist on the truck or rail routes.

6. Assume that altering operations at one site will have no effect (except perhaps cargo quantities) on operations at other sites. In particular, there will be no monopoly situation where costs will vastly rise due to lack of competition from other closed sites.

7. For lack of any better data, uniform flow of cargo throughout the annual duration of cargo shipment periods is assumed.

8. Transshipment locations are uncapacitated. Any amount of cargo can go through any site. All locations can act as consolidated container stuffing sites. The cargo goes from

any supply location to at most 1 transshipment point, and then directly to a port, after being stuffed in a MILVAN.

9. The transportation time differences between both modes of transportation (truck and rail) are negligible. The only real time differences occur at the container stuffing sites, as they wait for adequate amounts of cargo to warrant a rail car as transportation.

10. There are no costs associated with MILVAN rentals because DOD owns them. However, there will be costs associated with the rentals of 89-foot flatcars.

APPENDIX B: DATA DERIVATION

A. OVERVIEW OF DATA

This section describes data used in the thesis, with an emphasis on derivation. The amount of cargo shipped annually is listed in the first section. The shipping rates for rail and truck, and the fixed, startup, closeup and handling costs are presented.

B. ANNUAL DEMAND CARGO

The amount of cargo originating at supply locations is determined with shipment records from the summer quarter of 1992. The volume is multiplied by 4 since most cost data are annual. Consolidations of shipments are made to the nearest large supplier. Table II, in Chapter IV, lists the locations used and the quantities to be moved annually.

C. REPRESENTATIVE CARGO UNIT

Shipment cost for cargo is based on weight and size. The base cargo figure is derived from the CARGO MISSION SUMMARY which has figures for pounds and MTONs. One MTON is used as the standard size shipment since it fits inside a MILVAN. The weight for all annual shipments is 210,162,124 pounds, comprising 321,604.4 MTONs. The average of 653.5 lbs/MTON is the standard weight per MTON used in this thesis.

D. SHIPPING RATES

1. Truck Transportation Rates

The truck transportation shipping rates are for a "representative cargo unit" of 1 MTON, from all suppliers to all possible container stuffing sites (Tables III-V, in Chapter IV). Some of the suppliers are not allowed as possible container stuffing sites in the model. The shipment locations are the result of consolidation of suppliers, based on geography and size.

2. Published Rail Rates

The published rail transportation shipping rates listed below are for a MILVAN with a representative unit of cargo, from all suppliers to any of the 3 ports receiving rail shipments. The derivation of this data is noteworthy and follows.

The rates in Table XX are dollars for 100 pounds of cargo shipped from a supply location to a port. This is the standard measure of shipment for published rail rates.

Table XX RAIL RATES TO PORTS: 100-LBS CARGO

DOLLAR RATES FROM SUPPLY SITES TO PORTS:

	PORTS		
SUPPLY SITES	**BAYONNE**	**NORFOLK**	**NEW ORLEANS**
ANNISTON	8.62	6.85	5.88
HARTFORD	3.58	6.28	12.15
WASHINGTON	4.42	4.23	7.88
JACKSONVILLE	9.54	7.18	7.18
ATLANTA	8.85	7.05	6.39
CHICAGO	9.00	9.10	9.60
LEXINGTON	8.28	7.05	8.14
NEW ORLEANS	11.46	9.94	0.00
ST LOUIS	9.00	9.00	7.76
GULFPORT	11.18	9.90	2.82
CHERRY PT	6.65	4.04	9.90
BAYONNE	0.00	5.43	6.02
SENECA	5.13	6.65	11.58
COLUMBUS	7.33	7.33	9.24
MECHANICSBURG	4.05	5.13	10.66
PHILADELPHIA	3.17	4.68	11.07
CHARLESTON	8.10	6.45	8.42
MEMPHIS	9.94	9.24	5.69
DALLAS	13.07	11.91	6.48
NORFOLK	5.43	0.00	9.94

Only MILVANs are considered as potential cargo for rail shipments. The railroads charge for a minimum weight of 24,000 pounds per MILVAN, regardless of the amount of cargo inside the MILVAN. The rates in Table XX are multiplied by 240, for the overall dollar rate for a MILVAN shipped via rail. This 240 multiplier applies even though the number of MTONs which can fit in a MILVAN is estimated to weigh only 20,912 pounds for MTMCEA shipments (20 x 8 x 8 = 1280 cubic feet; 1280 cubic feet per MILVAN + 40 cubic feet per MTON = 32 MTONs per MILVAN; 32 MTONs x average weight of 653.5 pounds

per MTON = 20,912 pounds). The 24,000 pound MILVAN rates are listed in Table XXI.

Table XXI RAIL RATES TO PORTS: 24,000 POUND MILVAN

DOLLAR RATES FROM SUPPLY SITES TO PORTS:

	PORTS		
SUPPLY SITES	**BAYONNE**	**NORFOLK**	**NEW ORLEANS**
ANNISTON	2068.8	1644.0	1411.2
HARTFORD	859.2	1507.2	2916.0
WASHINGTON	1060.8	1015.2	1891.2
JACKSONVILLE	2289.6	1723.2	1723.2
ATLANTA	2124.0	1692.0	1533.6
CHICAGO	2160.0	2184.0	2304.0
LEXINGTON	1987.2	1692.0	1953.6
NEW ORLEANS	2750.4	2385.6	0.0
ST LOUIS	2160.0	2160.0	1862.4
GULFPORT	2683.2	2160.0	676.8
CHERRY PT	1596.0	969.6	2376.0
BAYONNE	0.0	1303.2	1444.8
SENECA	1231.2	1596.0	2779.2
COLUMBUS	1759.2	1759.2	2217.6
MECHANICSBURG	972.0	1231.2	2558.4
PHILADELPHIA	760.8	1123.2	2656.8
CHARLESTON	1944.0	1548.0	2020.8
MEMPHIS	2385.6	2217.6	1365.6
DALLAS	3136.8	2858.4	1555.2
NORFOLK	1303.2	0.0	2385.6

The model assumes MILVANS are sent to the least expensive port from any consolidation site. So only the least expensive entry in each row of Table XXI applies.

The model uses the least expensive route between trucking and rail shipments. The rail rates per MTON in a MILVAN are developed (divided rates in Table XXI by 32 MTONs per MILVAN, and then by 4 MILVANs per flatcar) and compared to the truck rates (Table VI, in Chapter IV). In all cases, the

rail rates are less expensive than the truck rates for like shipments.

These rail rates are only achieved if a completely loaded MILVAN is shipped. Lesser loaded MILVANs will have correspondingly larger rail costs, since the entire MILVAN receives a flat rate. This is very important. The truck rates for these routes are very close to the rail rates in most cases. Any increase in the rates per MTON for a rail route are likely to result in trucks being the least expensive option.

3. Negotiated Rail Rates

Another way to conduct this analysis is to use the average planning rate used by MTMCHQ. The standard rate of $2.20 per mile for an 89-foot flatcar applies. This rate is different than the published rates above. Those rates are for 1 MILVAN alone.

The $2.20/mile rate is for a flatcar that can carry 1, 2, 3, or 4 MILVANs each. This rate is subject to negotiation, but is the historical average. Assuming 4 MILVANs need to be shipped, and a flatcar is available at $2.20/mile, the costs of rail shipments to the ports can be developed. Table XXII lists the mileage between the supply sites and the ports.

Table XXII RAIL DISTANCES FROM SUPPLY SITES TO PORTS

	RAIL DISTANCES (MILES) PORTS		
SUPPLY SITES	BAYONNE	NORFOLK	NEW ORLEANS
ANNISTON	910	630	389
HARTFORD	127	471	1402
WASHINGTON	218	191	1062
JACKSONVILLE	915	593	544
ATLANTA	821	535	470
CHICAGO	786	848	920
LEXINGTON	691	561	742
NEW ORLEANS	1280	1005	0
ST LOUIS	934	900	672
GULFPORT	1222	936	72
CHERRY PT	522	173	955
BAYONNE	0	349	1280
SENECA	251	508	1322
COLUMBUS	528	538	904
MECHANICSBURG	178	295	1111
PHILADELPHIA	88	266	1196
CHARLESTON	707	385	721
MEMPHIS	1072	867	388
DALLAS	1524	1312	494
NORFOLK	349	0	1005

The railroads are not charged a flat fee for a MILVAN in this case. Instead they charge a flat fee for the flatcar. The number of MTONs per flatcar is 128 (32 MTONs per MILVAN x 4 MILVANs per flatcar). This figure is the best possible case for MTMCEA shipments. It results in the least expensive rail shipments. Rail shipments with 1, 2 or 3 MILVANs per flatcar are correspondingly more expensive.

The rail rates for a flatcar can be developed by multiplying the $2.20/mile rate times the number of miles to a port. Since 128 MTONs can fit on a flatcar, divide the

flatcar rates by 128 to obtain the rate per MTON. Once again, MILVANs on flatcars are assumed sent to the least expensive port from any container stuffing site. Table XXIII lists the resulting rail rates per MTON.

Table XXIII RAIL RATES TO PORTS: 1 MTON w/4 MILVANS on 89-FOOT FLATCAR

	DOLLARS PORTS		
SUPPLY SITES	**BAYONNE**	**NORFOLK**	**NEW ORLEANS**
ANNISTON	-	-	6.68
HARTFORD	2.18	-	-
WASHINGTON	-	3.28	-
JACKSONVILLE	-	-	9.35
ATLANTA	-	-	8.07
CHICAGO	13.5	-	-
LEXINGTON	-	9.64	-
NEW ORLEANS	-	-	0.0
ST LOUIS	-	-	11.55
GULFPORT	-	-	1.23
CHERRY PT	-	2.97	-
BAYONNE	0.0	-	-
SENECA	4.31	-	-
COLUMBUS	9.07	-	-
MECHANICSBURG	3.06	-	-
PHILADELPHIA	1.51	-	-
CHARLESTON	-	6.61	-
MEMPHIS	-	-	6.67
DALLAS	-	-	8.49
NORFOLK	-	0.0	-

These rates are substantially lower than the published rail rates. It should be noted that all figures in Table XXIV are for 4 MILVANs per flatcar. The rates increase as the amount of MILVANs per flatcar are reduced.

E. OTHER COSTS

Table VIII, in Chapter IV, lists the other costs used in the model.

1. Fixed Costs

To develop the fixed costs of the 3 ports' container stuffing activities, MTMCEA billing documents are investigated. The CARGO MISSION SUMMARYs for fiscal year 1992, for Bayonne, Norfolk, and New Orleans list the amounts of "premium" cargo shipped through the sites. "Premium" is the cargo that "can" be stuffed at the container stuffing sites. The FINAL COST OF CARGO MISSIONS BY FACILITY for fiscal year 1992 breaks down costs by code. This thesis only considers codes 77 and 79.

Code 77 has 7 blocks of EXPENSE ACCOUNT CODES, with first digits 1 through 7. The codes beginning with digits 1 (Allocated Direct Cost) and 2 (Contractual Stevedore and Related Services) are the only accounts involving stuffing costs of containers. These are the only costs saved if the cargo is not stuffed in a container at the ports.

Within each code all costs of accounts with first digits 1 or 2 on the EXPENSE ACCOUNT CODES report are added. These costs are then subtracted from the costs of that particular code as listed on the CARGO MISSION SUMMARY. The result is the fixed cost per MTON of this code of cargo moved through this port.

Then a weighted average, based on the annual amounts of cargo moved per code, is taken to determine a per MTON cost of containerizable cargo at the port. This figure is multiplied times the actual number of MTONs shipped through that port in FY 92, as listed on the CARGO MISSION SUMMARY. The result is the fixed cost figure at that port. The model uses these 3 derived figures.

It should be noted that the fixed costs for the ports do not include the price of buildings, rentals, and leases for real property. This is because these costs would continue, even if the container stuffing activities are closed.

The projected fixed costs of the potential container stuffing sites also had to be developed. The fixed costs at the new stuffing sites would be much larger than those at the ports if building rentals are included in the model. The fixed costs of the proposed stuffing sites include the labor and supplies used to stuff containers. However, the proposed sites would also have to build or rent buildings and space that is not currently available to them. However, these costs would have forced the model to exclude opening any of these sites since the handling costs at the ports and potential stuffing sites are very close.

This thesis assumes that the building costs saved (in the long run) at the ports if the container stuffing operations were closed, are the same as the costs of renting or constructing buildings at the proposed sites. To allow a

fair comparison the fixed costs of these sites are determined in a manner similar to the port's fixed costs.

The US Department of Labor's Bureau of Labor Statistics Employment and Earnings Manual for 1991, provides average hourly wage rates. The ratio of the hourly earnings rates for the proposed stuffing sites, as compared to an average port rate, are used to determine fixed costs at the proposed sites. This ratio is multiplied by the fixed cost average of the 2 Army ports [($715,584 + $493,495) ÷ 2 = $604,539)]. Norfolk is dismissed from this analysis because of its unique (Navy) accounting figures. The resultant fixed costs are listed in Table XXIV.

Table XXIV CONTAINER STUFFING SITE FIXED COSTS

LOCATION	WAGE RATIO (÷11.81)		MULTIPLIED BY AVERAGE FIXED COSTS =	RESULTANT FIXED COSTS
ANNISTON	.8661	x	$604,539	$523,591
JACKSONVILLE	.8331		"	503,641
ATLANTA	.9449		"	571,228
NEW ORLEANS	N/A		N/A	493,495
GULFPORT	.9729		"	588,156
CHERRY PT	.8814		"	532,840
BAYONNE	N/A		N/A	715,584
COLUMBUS	1.1100		"	671,038
MECHANICSBURG	.9771		"	590,695
PHILADELPHIA	1.0601		"	640,871
CHARLESTON	.8086		"	488,830
MEMPHIS	.8746		"	528,729
NORFOLK	N/A		N/A	253,548

2. Startup Costs

No startup costs are available for the potential container stuffing sites. Particular sites' costs may be developed after the actual sites are selected. The startup costs are effectively eliminated from the study with the assumption that the costs would be about equal to the ports' annual building overhead in the long run.

3. Closeup Costs

No closeup costs are available for the ports' container stuffing activities. This is because operations at a port would not end if the container stuffing activity at a port were closed.

4. Handling Costs

Each of the ports have a handling cost that is based on the costs of stuffing the cargo into a container. This per unit cost is derived from the costs on the FINAL COST OF CARGO MISSIONS BY FACILITY. The costs are the totals from the FINAL COST OF CARGO MISSIONS BY FACILITY, for codes 77 and 79, and with the EXPENSE ACCOUNT CODES, with first digits 1 and 2.

In short, this cost is the figure listed on the CARGO MISSION SUMMARY, minus the fixed cost associated at that port. It is $14.57 for Bayonne, $26.40 for Norfolk and $14.50 for New Orleans.

The handling costs at the possible container stuffing sites are developed using the US Department of Labor's Bureau

of Labor Statistics Employment and Earnings Manual for 1991. The most similar occupation to stuffing operations for which data are available is general manufacturing. Pages 148-152 list the average hourly earnings for production workers on manufacturing payrolls, by states and selected areas of the country. While manufacturing is not exactly the same as stuffing operations, the ratio of earnings for different areas is similar, since both are limited skills labor.

Table XXV lists the resultant hourly wage rates for the possible container stuffing sites. The 3 ports' hourly pay for October 1991 are averaged to be [($10.31 + $13.63 + $11.49) + 3] = $11.81. Then the 13 locations' hourly wage rates are listed. A ratio of the hourly wages of the possible stuffing sites compared to the average of the ports is derived. This ratio is multiplied by the average of the handling costs at the 2 Army run ports ($14.50 + $14.57)+2 = $14.53) to obtain the resultant wage rates at the potential stuffing sites.

Table XXV CONTAINER STUFFING SITE HOURLY WAGE RATES

LOCATION	HOURLY WAGES	WAGE RATIO (÷11.81)		MULTIPLIED BY AVERAGE HANDLING COSTS	RESULTANT WAGE RATE
ANNISTON	10.22	.8661	x	$14.53	$12.58
JACKSONVILLE	9.84	.8331		"	12.10
ATLANTA	11.16	.9449		"	13.73
NEW ORLEANS	11.49	N/A		N/A	11.49
GULFPORT	11.49	.9729		14.53	14.13
CHERRY PT	10.41	.8814		"	12.81
BAYONNE	10.31	N/A		N/A	10.31
COLUMBUS	13.11	1.1100		14.53	16.13
MECHANICSBURG	11.54	.9771		"	14.19
PHILADELPHIA	12.52	1.0601		"	15.40
CHARLESTON	9.55	.8086		"	11.75
MEMPHIS	10.33	.8746		"	12.71
NORFOLK	13.63	N/A		N/A	13.63

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